Cooperative Extension

Citrus Arthropod Pest Management in Arizona

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David Kerns[1], Glenn Wright[2], and John Loghry[3]

[1]Department of Entomology, Yuma Agricultural Center - Valley Station, 6425 W. 8th St., Yuma, AZ 85364
[2]Department of Plant Science, Yuma Agricultural Center - Mesa Station, RR1, Box 40M, Somerton, AZ 85350
[3]Arizona Crop Improvement Association, Yuma Agricultural Center - Mesa Station, RR1, Box 40M, Somerton, AZ 85350

INTRODUCTION

Arizona is one of four states in the Unites States with significant citrus production with approximately 28,600 acres. Although Arizona comprises only 2.8% of the United States' total citrus production, it accounts for about 28% and 14.5 % of the nations lemon and tangerine production respectively.

Arizona citrus production is primarily relegated to relatively frost-free areas where sufficient and affordable irrigation water can be found. Yuma and Maricopa Counties account for more than 90% of the state's citrus acreage with 18,500 and 10,100 acres respectively. Minor acreages of commercial citrus production can also be found in Pinal, Pima and Mojave Counties.

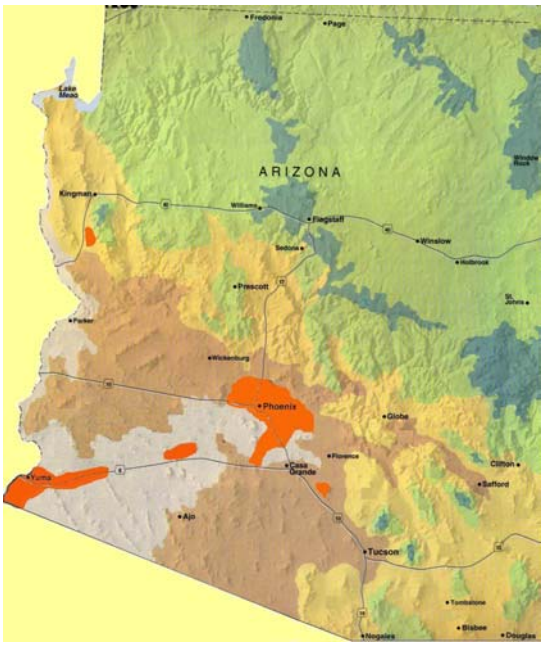

Figure 1. Citrus production areas of Arizona.

In Arizona, lemons comprise approximately 51.7% of the State's total citrus production, followed by tangerines at 19.6%, navel oranges at 12.2%, Valencia oranges at 9.4%, and Grapefruit at 7.1%.

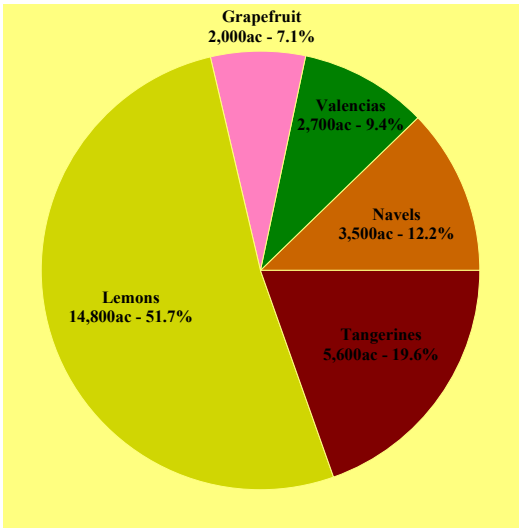

Figure 2. Approximate distribution of citrus types in Arizona.

However, citrus type distribution differs significantly between Yuma and Maricopa Counties. Yuma accounts for more than 90% of the state's lemon acreage, while Maricopa County contains 70, 71, and 62% of Arizona's grapefruit, orange, and tangerine acreage respectively. There are also some differences between these principal production areas in growing costs. In Yuma, approximate operating costs for citrus ranges from $800 to $900 per acre while in Maricopa County the costs range from $600 to $700 per acre. These differences are due to higher insecticide, water, and fertilizer use in Yuma relative to Maricopa. The higher water and fertilizer use in Yuma is due primarily due to the fact that most of the Yuma citrus is grown on

sandy soil where most of the Maricopa citrus is on heavier soils. Increased insecticide use in Yuma is due to higher insect pressure from citrus thrips and woolly whitefly.

Lemon market prices are usually highest during the late summer and early fall when fruit availability from other growing locations is limited. Furthermore, prices can vary considerably throughout the harvest season (last August through April), depending on lemon quality, size, demand and availability. Interior and exterior fruit quality can significantly influence the price a grower will receive for his crop. Because of the high growing costs required to produce lemons, growers intensively manage their crops for the highest possible yield and minimal insect damage.

Below is a compendium of common insect and mite pests of Arizona citrus. Other pests do occur, but are rarely of economic importance. There are many insecticides registered for use in citrus, more than can be adequately addressed in this document. The insecticides listed in this document are those commonly used at the time of publication, or have significant potential for use. Refer to specific insecticide labels for details and changes.

INSECT PESTS

CITRUS THRIPS
Scirtothrips citri

DESCRIPTION AND LIFE HISTORY: Adult citrus thrips are small, orange-yellow insects with fringed wings. The females measure 0.6 to 0.88 mm. Males are similar in appearance but somewhat shorter and narrower. Under warm conditions, adult citrus thrips may live as long as 25 to 35 days, or longer under cool conditions.

The eggs (0.2 mm) are oviposited under the cuticle of new leaves, stems, and fruit. One female may lay as many as 250 eggs. They hatch is 6 to 8 days during warm weather. Those laid in the fall pass the winter and hatch in March (first generation) about the time new foliage growth commences. However, in the Yuma area, it is not uncommon to find citrus thrips throughout the year during warm periods.

There are two active nymphal stages (first and second instars) requiring 4 to 14 days for development. First instar larvae feed actively on tender leaves and fruit, especially under the sepals of young fruit. The third and fourth instars are pupation stages and do not feed. They complete development on the ground in litter beneath the tree or in the crevices of the tree. The third instar is the prepseudopupal stage and the fourth instar is known as the pseudopupal stage. A single generation may be completed in a period of 15 days. In Yuma, there may be as many as 10 to 12 generations per year, while in Maricopa County they will usually complete 8 to 10 generations per year.

Figure 3. Second instar citrus thrips.

Citrus thrips tend to be more numerous on the south side of citrus trees, especially the southeast quadrant. Additionally, they tend to be more numerous between 2 to 3 meters than at other heights.

Figure 4. Citrus thrips adult.

Citrus thrips have a very broad host range. These hosts include among others, all types of citrus, alfalfa, rose, grape, laurel, cotton, date, fir, and various grasses and deciduous trees.

Other species of thrips also occur on citrus in Arizona but none of these are of economic importance. These include the western flower thrips, *Frankliniella occidentalis*, the onion thrips, *Thrips tabaci*, and *Bregmatothrips sonorensis*. Of these thrips, the

western flower thrips is most common and can be very abundant during bloom, on the flowers, small fruit, and flush growth. Care should be taken to not confuse western flower thrips with citrus thrips. Western flower thrips are more tolerant to insecticides than citrus thrips and when mistakenly identified may give the impression of poor insecticide efficacy.

Figure 5. Adult western flower thrips.

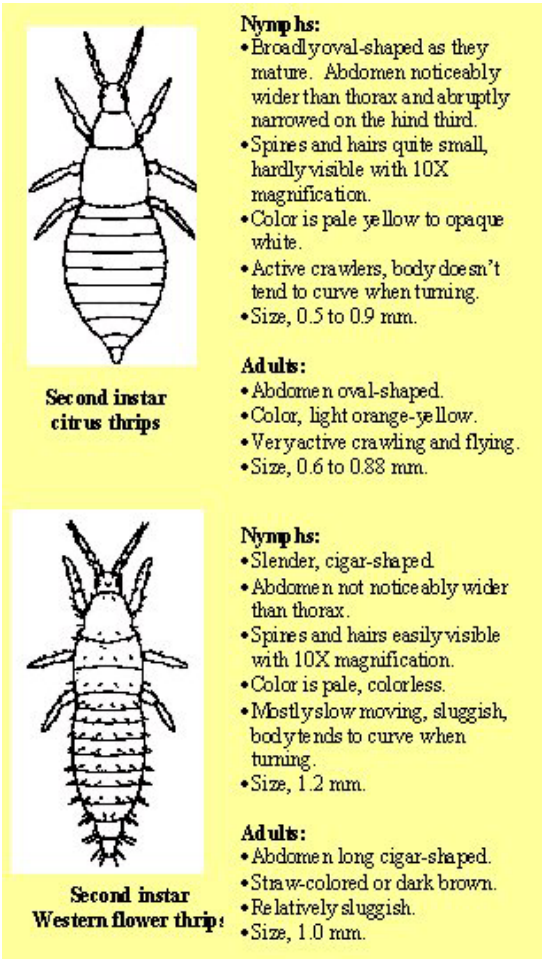

Figure 6. Distinguishing characteristics of citrus thrips and western flower thrips.

DAMAGE: Citrus thrips is the most economically damaging insect pest of Arizona citrus. On fruit, the citrus thrips punctures epidermal cells, leaving scabby, grayish or silvery scars on the rind. Second instar nymphs do the most damage because they feed mainly under the sepals of young fruit. As the fruit grows, damaged rind tissue moves outward from beneath the sepals as a conspicuous ring of scarred tissue. This damage, although entirely cosmetic, may result in a reduced quality rating and/or if severe may render the fruit unsuitable for fresh market.

Figure 7. Rind scarring on an orange due to the feeding by citrus thrips beneath the sepal when the fruit was young.

Feeding by citrus thrips on new flush growth will also result in damage to the developing foliage. These leaves will appear distorted and thickened with gray streaks usually parallel to the midvein. Extensive feeding on small leaves and leaf buds can result in significant defoliation and limb "buggy whipping". Fruit bearing trees do not appear to be adversely affected by this damage, but growth may be stunted on non-bearing trees.

Figure 8. Leaves damage (left) and the "buggy

whipping" effect caused by citrus thrips feeding when the leaves were small and subsequent defoliation.

MONITORING: Monitoring citrus for citrus thrips begins at the initiation of bloom, but becomes critical at petal fall (90% blossom drop) in late-March to early-April. On mature trees, sampling should continue until 70 to 90% of the fruit reach a minimal size of 1 inch in diameter. Once the fruit reaches this size it is no longer susceptible to citrus thrips scarring. On immature trees, sampling should continue until mid- to late-October when the fall flush ceases.

Figure 9. Once the fruit reaches 1 inch in diameter, it is no longer susceptible to significant citrus thrips scarring.

On immature trees and as a general indicator of citrus thrips age distribution regardless of tree age, flush should be sampled. The flush is best sampled by tapping it against a dark colored notebook or similar object, and observing what is dislodged. Although no treatment threshold exists, treatments should probably be applied when the citrus thrips population approaches 10 thrips per flush, when there are a large number of leaves less that one-half inch in length.

On mature trees it is important to sample individual fruit using a hand lens. Count the number of fruit with at least one immature citrus thrips. Samples should be taken from various locations throughout the grove, and from all four quadrants of the tree. Twenty to fifty samples may have to be taken to obtain an adequate estimate of the citrus thrips population. Treatments should be applied when 10% or more of the fruit are infested with immature citrus thrips.

Adult citrus thrips tend to be significantly more attracted to white and yellow compared to other colors. Thus yellow sticky cards can be used as a relative indicator of citrus thrips activity.

CONTROLS:

Cultural: There are no specific cultural control techniques utilized for citrus thrips.

Biological:
•Predators. A number of natural enemies attack citrus thrips including predaceous mites, spiders, lacewings, minute pirate bugs, etc. However, during most years, citrus thrips densities are too high to be adequately controlled with natural enemies, thus making insecticide use unavoidable. However, conservation of natural enemies, namely predaceous mites, will often prevent citrus thrips resurgence.

Commonly used Chemicals: Citrus thrips are less of a problem in groves that receive minimal pesticide treatments than in groves that are heavily treated, especially those treated with broad-spectrum insecticides. Thrips populations tend to increase after treatments with insecticides that kill predacious mites. Citrus thrips has a history of rapidly developing resistance to chemicals that are used repeatedly and frequently for its control. With the limited number of pesticides available for control of citrus thrips, growers should monitor citrus thrips levels carefully to avoid unnecessary treatments and should avoid sequential applications of the same or similar insecticides.

•**Abamectin.** 7 day pre-harvest interval (PHI). Abamectin (AGRI-MEK) is applied at a rate of 0.012 to 0.024 lbs-ai per acre. It is occasionally used in the Yuma area. It cannot be applied to nurseries or by aircraft. It should always applied in combination with a horticultural spray oil at a rate of not less that 1.0 gal per acre. Abamectin is relatively nontoxic to beneficial insects and mites. It is most effective if substantial numbers of predators are present. Residual activity of abamectin is short; 3 to 4 days. Do not exceed three applications or 0.048 lbs-ai per acre per year, and allow at least 30 days between applications. The restricted entry interval for abamectin is 12 hours.

•**Cyfluthrin.** 0 day PHI. Cyfluthrin (BAYTHROID, RENOUNCE) is a broad-spectrum pyrethroid insecticide that is widely used at a rate of 0.1 lbs-ai per ac. It is fairly efficacious early in the season, but may not provide adequate or lengthy control once temperatures consistently exceed 32ºC (95ºF). Cyfluthrin provides a moderately lived residual control of about 5 days. Because some citrus thrips resistance to pyrethroids has been reported in Yuma, only one application per crop per season is permitted. Care should be taken to not apply cyfluthrin following fenpropathrin as well since these are similar

chemistries. Cyfluthrin is toxic to both beneficial mites and beneficial insects, and may disrupt biological control. Do not apply to trees ≤ 3 years of age. The restricted entry interval for cyfluthrin is 12 hours.

•**Dimethoate.** 15 day PHI. Dimethoate (DIMETHOATE) is an organophosphate that is widely used to control citrus thrips, and is the product of choice in areas other than in Yuma. It is used in Arizona at a rate of 2.0 lbs-ai per acre. Use of dimethoate is prohibited during any time of day when the grove has 10% or more open blooms until there has been at least 75% petal fall on the north side of the trees. Dimethoate may be used during the time between one hour after sunset until three hours before dawn under the following conditions: before petal fall when less that 10% of the blooms have opened, after the initiation of petal fall when there are less than 25% open bloom remaining in the grove, and it is between the calendar dates of February 15 and May 1. Dimethoate is toxic to bees, and both beneficial mites and beneficial insects, and may disrupt biological control. Dimethoate offers good control under cool conditions, and moderate control under hot conditions. Dimethoate has a short residual, generally providing about 3 days of control under constant thrips pressure. Applications to citrus seedlings are prohibited, and no more that 2 applications can be made to trees that have mature fruit. The restricted entry interval for dimethoate is 4 days.

•**Fenpropathrin.** 1 day PHI. Fenpropathrin (DANITOL) is a broad-spectrum pyrethroid insecticide that is used at a rate of 0.4 lbs-ai per acre. It is recommended that no more than one application be made per year, but there is an allowance of up to 0.8 lbs-ai per acre per year. Do not apply if the temperature exceeds 34.4ºC (94ºF). In recent years, fenpropathrin has only provided marginal thrips control, and where used, the citrus thrips population has often grown to become much greater than where no insecticides were used. Fenpropathrin is toxic to beneficial insects and is especially toxic to predatory mites. Additionally, citrus thrips resistance to fenpropathrin has been reported in Yuma County. These factors may be the reason severe citrus thrips resurgence following use of this product. The restricted entry interval for fenpropathrin is 24 hours.

•**Formetanate Hydrochloride.** 7 day PHI. Formetanate HCL (CARZOL) is a carbamate that is commonly used in Yuma and occasionally in other parts of the state. Most applications of formetanate HCL range from 0.9 lbs-ai per acre to 1.15 lbs-ai per acre. Formetanate HCL is a broad-spectrum insecticide that is persistent, providing residual control for 10 to 14 days, and works well under both hot and cool conditions. Do not apply more than 1.15 lbs-ai per acre per season. Formetanate HCL, may not be applied once the fruit is greater than 1.0-inch in diameter. However, if mature grapefruit or Valencia oranges from the previous season are present, an application may be made to the new crop if a 30 day preharvest interval is observed for the unharvested crop. Formetanate HCL is toxic to both beneficial mites and beneficial insects and disrupts biological control. The restricted entry interval for formetanate HCL is 16 days for hand labor activities and 10 days for activities where the worker will not contact treated foliage.

•**Kaolin.** 0 day PHI. Kaolin (SURROUND, SNOW) is a refined clay mineral product that primarily disrupts citrus thrips feeding and behavior. Kaolin has little knockdown activity, but may result in 20 to 30% thrips mortality. Thus kaolin reduces thrips damage best when used preventively. Kaolin is applied prior to heavy thrips pressure at rates of 35 to100 lbs per acre. The rate used is dependent on the effectiveness of the spray application equipment. Good coverage is essential to maximize control. Typically on mature citrus, kaolin should be applied just before or at petal fall, again 10 to 14 days later and a third time 3 to 5 weeks following the second application if needed. Once the fruit reaches 1.0-inch in diameter, further applications of Surround are not necessary. It is recommended that a non-ionic surfactant be used with kaolin. Kaolin is non-toxic to bees, but may disrupt the activity of some parasitic wasps. Kaolin has been shown to protect fruit from sunburn. Surround has been shown to increase fruit earliness and is an OMRI approved organic treatment. The restricted entry interval is 4 hours.

•**Spinosad.** 1 day PHI. Spinosad (SUCCESS, ENTRUST), a macrocyclic lactone isolated from the soil microorganism *Saccharopolyspsora spinosa*. It is normally applied to citrus at rates of 0.06 to 0.10 lbs-ai per acre. Spinosad is highly effective towards citrus thrips and is a product of choice in Yuma. Spinosad works well under hot and cool conditions, and provides residual control for 10 to14 days. Spinosad works best when used with a non-ionic surfactant or with a narrow-range oil. Spinosad is relatively nontoxic to beneficial insects and mites. Do not buffer spinosad below a pH of 6, since residual control will be much shorter, although initial insect knock down will not be affected.. Spinosad may not be applied more than twice per year unless another class of products is used in the interim of 30 days or 2 sprays, whichever is longest. Spinosad may not be used in nurseries. The restricted entry interval is 4 hours.

WOOLLY WHITEFLIES

Aleurothrixus floccosus

DESCRIPTION AND LIFE HISTORY: The woolly whitefly is a relatively new pest to Arizona, arriving in 1996 and is currently restricted to the Yuma area. Adult woolly whiteflies are small, flying insects resembling small white-winged moths with a yellowish-white abdomen and a light dusting of white powder (scales). The adults are about 1.5 mm in length and can be found roosting on the undersides of fully expanded leaves. Adult woolly whiteflies are not as active as most other whitefly species and when disturbed, will reluctantly fly and will usually quickly resume roosting. Adult woolly whiteflies may live as long as 24 days.

Figure 10. Adult woolly whitefly.

The eggs are laid on the underside of fully-expanded leaves and are distinctive of the species. They are attached to the leaf with a stalk, small (<0.3 mm in length), sausage shaped, and are laid in circle or semi-circular patterns. These egg circles are usually surrounded by a light dusting of waxy scales. When first laid, the eggs are pale white, but darken to brown with age. The eggs require 4 to 12 days hatch, although some eggs may overwinter. One female will typically lay as many as 200 eggs.

The immature stages (nymphs) are flattened and oval shaped, resembling scales. As they age they cover themselves with "woolly" white waxy filaments. The woolly whitefly goes through four nymphal stages. The first instar or crawler is about 0.3 mm in length and is the only nymphal stage that is mobile.

Figure 11. Second instar woolly whiteflies and eclosed eggs.

The crawlers will usually settle near the eggs from which they hatched. The second to fourth instars are sedentary, and will often be completely obscured by copious amounts or waxy filaments, droplets of honeydew, and cast skins. The fourth instar serves as the "pupal stage" and as about 0.6 mm in length. The fourth instar represents the most common stage for overwintering. Adults emerge from the pupae by vertically splitting its skin.

Figure 12. Third and fourth instar woolly whitefly covered by woolly waxy filaments.

During warm weather, woolly whiteflies require about 21 day to complete its life cycle. In Arizona, adults will emerge from overwintering in March or April. These flights will be the first of five to six generations. Populations tend to be greatest in August, although very high populations are not uncommon in late May and June. The fifth or sixth generation (depending on fall temperatures) will occur in October or November, during which it will overwinter primarily as third or fourth instars or sometimes as eggs.

Woolly whiteflies may be found on all varieties of citrus, some types of guava (*Psidium* sp. only), sea grape (*Coccoloba uvifera*), and it has been reported to

occasionally be found on yellow trumpet flower (*Tecoma stans*). Among citrus, grapefruit, tangelos and tangerines appear to be most heavily colonized, followed by oranges and lemons, although large populations can found on any citrus type.

DAMAGE: Woolly whiteflies suck phloem sap, causing leaves to wilt and drop when populations are large. Honeydew droplets collect dust and support the growth of sooty mold; large infestations where copious amounts of honeydew are produced, can result in the blackening of entire trees. This reduces photosynthesis, resulting in decreased fruit size. Honeydew and sooty mold can also contaminate the fruit. Although this contamination can be washed off at the packing shed, harvest is slowed in infested groves and harvest crews are hesitant to pick heavily contaminated fruit.

Figure 13. Sooty mold growth from woolly whitefly honeydew accumulation on citrus leaves.

MONITORING: Woolly whitefly monitoring should begin in March. Sample fully-expanded leaves by gently turning them over to observe the underside of the leaf, looking for adults, eggs, colonies of immatures, and adult parasitoids. Attention should be rendered to which growth stages of the whitefly are present since this will aid in making a proper management decision. Weekly sampling should be conducted until cool temperatures occur in late October or November.

When colonies of immature whiteflies are common it is important to determine how much parasitism is occurring. Gently scrap away the waxy accumulation revealing the large nymphs and eclosed pupae (pupae from which the adult insect has already emerged). Eclosed pupae exited by woolly whiteflies will have a vertical split on the anterior dorsum of the empty exuvae (skin) (a 10X or better hand lenses will be necessary). An eclosed pupae exited by a parasitoid will have a round hole on the anterior dorsum of the exuvae.

CONTROL

Cultural:

- **Pruning & hedging.** Light infestations can be greatly reduced by hedging. This technique has proven to be especially effective on trees ten years old or younger. Additionally, pruning will aid in opening up the canopy to maximize spray penetration and coverage.

Biological:

- **General Predators and Parasitoids.** Establishing biological control of woolly whitefly is ultimately the

Figure 14. Eclosed pupae (left) from an adult woolly whitefly leaving a vertical split and (right) from a parasitoid leaving a round hole.

Figure 15. *Eretmocerous* sp. is a common and very effective parasitoid of woolly whitefly in Arizona. They appear as small yellow "gnats" with three distinctive red dots (ocelli) on the tops of their heads.

best and most effective means of controlling this pest. There are several natural enemies that attack the immature stages of woolly whiteflies. Among parasitoids, an *Eretmocerus* sp. has proven to be extremely effective. This parasitoid is common, particularly during late summer and early fall. There are also a number of predacious insects that aid in suppressing woolly whitefly. Yuma spider mite and *Tydeus* spp. are common predaceous mites of woolly whitefly.

General insect predators found feeding on woolly whitefly include: lacewings, coccinellid beetles, nabids, *Orius*, and six-spotted thrips. Large outbreaks of woolly whitefly can be prevented or large infestations brought under control by utilizing selective insecticides that will conserve whitefly natural enemies. When *Eretmocerous* sp. adults, parasitoid eclosed pupae, and or predators are common, chemical control is usually not necessary.

Woolly Whitefly Management Guidelines for Arizona Citrus

Establishing biological control is key to sustainable management

- **Spring**
  - Use spray oils to suppress woolly whitefly populations before prohibitive due to high temperatures.
  - Avoid harsh insecticides for citrus thrips control, especially in May and June.
  - Where moderate to large colonies of immature whiteflies are present in conjunction with high citrus thrips infestations; use Provado or Danitol + OP tank-mixes since these will control the whiteflies and aid in citrus thrips control.
- **Summer / Fall**
  - When adults are present and/or small colonies of immatures; chemical control is not advisable.
  - When moderate to large colonies of whitefly immatures are present; use Esteem or Applaud. Provado or Danitol + OP tank-mixes are also effective but are detrimental to parasitoids.
- **For the most effective and sustainable management**
  - Try to preserve natural enemies.
  - Treat before the infestation becomes heavy.
  - Make ground applications only; good coverage is essential.
  - On groves with large trees, or for tight groves, use high spray volumes; 200 to 500 gal/ac.
  - The addition of narrow-range spray oil with insecticide treatments will aid in control

Figure 16. Current University of Arizona woolly whitefly management guidelines.

Commonly used Chemicals: Since woolly whitefly is a relatively new pest in Arizona, chemical control techniques are still being evaluated.

•**Pyriproxyfen.** 1 day PHI. Pyriproxyfen (ESTEEM) is an insect growth regulator used to control whiteflies though control is slow, taking about a month to see visual results. It acts by sterilizing the adults causing them to lay unviable eggs, and can cause nymphal mortality. Pyriproxyfen should be applied when a majority of the woolly whitefly population is small nymphs. It is applied at rates of 0.05 to 0.07 lbs-ai per acre. Pyriproxyfen is fairly selective, and although it is not know to disrupt parasitoid activity; it can negatively impact vedalia and other lady beetle populations, as well as lacewing larvae. Do not exceed 0.17 lbs-ai per acre per season. Do not exceed two applications per season. Allow at least 21 days between applications. The restricted entry interval for pyriproxyfen is 12 hours.

•**Imidacloprid.** 0 day PHI. Imidacloprid (PROVADO, ADMIRE) is a neonicotinoid insecticide that mimics the nerve poisoning action of nicotine. Admire is the soil-applied formulation and Provado is the foliar formulation of this chemical. When applied to the soil through a drip-irrigation or emitter system, Admire has effectively controlled woolly whitefly. However, at this time, it is not certain if similar efficacy would occur if Admire were injected around trees with a shank applicator followed by flood irrigation. Regardless of

application method, it may take as long as six weeks before a fully effective dosage of Admire is distributed within the tree. Admire is applied at a rate 0.25 to 0.5 lbs-ai per ac. No more than 0.5 lbs-ai per acre of Admire may be applied per acre per year. Provado has shown good activity towards woolly whitefly and can be applied at 0.125 to 0.25 lbs-ai per acre. Effective timing in April and May maybe beneficial since high rates of Provado have citrus thrips efficacy under cool condition. Provado is active towards whitefly nymphs, but is especially active against the adults. Provado may not be applied during bloom or within 10 days before bloom. Do not exceed 1.0 lbs-ai per acre of Provado per year, and allow at least 10 days between applications. Imidacloprid is safe towards many beneficial insects, especially when applied as a soil treatment. The restricted entry interval for imidacloprid is 12 hours.

•**Buprofezin.** 60 day PHI. Buprofezin (Applaud) is an insect growth regulator that disrupts the molting process through chitin synthesis inhibition. Buprofezin has activity on many whitefly species, scales, and mealybugs. However, the current Applaud label only lists California red scale under its citrus crop listing of controlled pests. Additionally, the labeled rates for buprofezin in citrus are those recommended for scales, 1.5 to 2.0 lbs-ai per acre. It is conceivable that a lower rate may be effective against woolly whitefly, and research is being conducted to test this hypothesis. Since this material affects molting, treatment should be made during peak crawler (1st instar) emergence. Woolly whitefly nymphs will go through several molts before they are killed, which may take several weeks before it is noticeable. Do not apply more than two applications per season, and allow at least 60 days between applications. Buprofezin is very selective and although it will negatively impact ladybeetle and lacewing larvae to a limited degree, it is very safe for predaceous mites and parasitoids. The restricted entry interval for buprofezin is 12 hours.

•**Cyfluthrin.** 0 day PHI. Cyfluthrin (BAYTHROID, RENOUNCE) is a broad-spectrum pyrethroid insecticide that is widely used at a rate of 0.1 lbs-ai per acre primarily for thrips control. Cyfluthrin is also fairly effective against woolly whitefly adults, and in combination with chlorpyrifos or dimethoate, and has proven to be effective against immature whiteflies as well. However, alone or in combination with chlorpyrifos, it is extremely toxic to predatory and parasitic insects and mites, which may lead to significant pest resurgence. Only one application per crop per season is permitted. Care should be taken to not apply cyfluthrin following fenpropathrin as well since these are similar chemistries. Do not apply to trees less than 4 years of age. The restricted entry interval for cyfluthrin is 12 hours.

•**Fenpropathrin.** 1 day PHI. Fenpropathrin (DANITOL) is a broad-spectrum pyrethroid insecticide that is widely used at a rate of 0.4 lbs-ai per acre primarily for mites and thrips control. Like cyfluthrin, it is fairly effective alone against woolly whitefly adults, and in combination with chlorpyrifos or dimethoate, it has proven to be effective against immature whiteflies as well. However, alone or in combination with chlorpyrifos, it is extremely toxic to predatory and parasitic insects and mites, which may lead to significant pest resurgence. It is recommended that not more than one application be made per year, but there is an allowance of up to 0.8 lbs-ai per acre per year, and sequential applications of fenpropathrin are not recommended due to the potential for the develop of resistance. Additionally, care should be taken to not apply fenpropathrin following cyfluthrin since these are similar chemistries. The restricted entry interval for fenpropathrin is 24 hours.

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate has proven to be effective against woolly whitefly, especially when applied in combination with fenpropathrin. Chlorpyrifos is applied at an average rate of 4 to 6 lbs-ai per ac. Thorough coverage is needed to be most effective. Chlorpyrifos is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects and mites, and parasitoids. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Dimethoate.** 15 day PHI. Dimethoate (DIMETHOATE) is an organophosphate that is widely used to control citrus thrips, and has proven to be efficacious towards woolly whitefly when applied at a citrus thrips rate of 2.0 lbs-ai per acre in combination with fenpropathrin. Use of dimethoate is prohibited during any time of day when the grove has 10% or more open blooms until there has been at least 75% petal fall on the north side of the trees. Dimethoate may be used during the time between one hour after sunset until three hours before dawn under the following conditions: before petal fall when less that 10% of the blooms have opened, after the initiation of petal fall when there are less than 25% open bloom remaining in the grove, and it is between the calendar dates of February 15 and May 1. Dimethoate is toxic to bees, both beneficial mites and beneficial insects, and

may disrupt biological control. Dimethoate offers good control under cool conditions, and moderate control under hot conditions. Applications to citrus seedlings are prohibited, and no more that 2 applications can be made to mature fruit. The restricted entry interval for dimethoate is 4 days.

CALIFORNIA RED SCALE

Aonidiella aurantii

DESCRIPTION AND LIFE HISTORY: California red scales are armored scales, occurring in isolated pockets in Maricopa County, primarily in the Phoenix area. Although California red scale can sporadically be found in Yuma, because of abatement efforts, Yuma County is considered a scale-free area.

The adult female are immobile, have a rounded cover, and appear as small reddish-brown spots or scabs. They are clearly visible when on the fruit. A fully grown female will be about 2.1 mm in diameter and can give birth to 100 to 150 yellowish colored crawlers (first instar). The crawler is the only stage in which female scales can move. Crawler can disperse from tree to tree on their own by crawling, but heavily rely on wind, birds, machinery, or labor crew to move longer distances. Once a crawler finds a suitable place to settle, it will form a nipple "scale like" stage. The female will go through three more molts to reach reproductive maturity.

Figure 17. An orange infested with California red scale.

After the crawler stage, the male scale will undergo two additional "scale like" molts before its final molt into a winged adult. In Arizona, there are four to seven distinct flights of male California red scale occurring between April and November. The male resembles a small "gnat", 0.8 to 1.2 mm in length.

Figure 18. An adult male California red scale, referred to as a flyer. (photo courtesy of Jack Kelly Clark, University of California, Regents).

DAMAGE: California red scale attacks all parts of the tree including twigs, leaves, branches, and fruit. Heavily infested fruit may be downgraded in the packinghouse and, if population levels are high, serious damage can occur to trees. Severe infestations cause leaf yellowing and drop, dieback of twigs and limbs, and occasionally death of the tree. Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest.

CONTROLS:

Regulatory:

The Arizona Department of Agriculture and The Yuma County Citrus Pest Control District both have programs to monitor for California red scale and abate infestations. Monitoring consists of a grid network of pheromone traps to detect the presence of male "flyers". If detected extensive scouting surrounding the area of the detection is conducted to find the infestation. All control efforts are currently being administrated through these agencies, and have been highly successful.

Figure 19. A pheromone trap used to monitor adult male California red scale activity.

Commonly used chemicals: The products listed here are those that have been used by The Yuma County Citrus Pest Control District program, or have potential use.

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate that is has been used to control California red scale, although it is no longer considered the product of choice. Chlorpyrifos is applied at an average rate of 4 to 6 lb-ai per acre. Thorough coverage is need for chlorpyrifos to be most effective. It is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects, mites, and parasitoids. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Pyriproxyfen.** 1 day PHI. Pyriproxyfen (ESTEEM) is an insect growth regulator which has is highly active against California red scale, and is currently the product of choice for abatement efforts. It acts by sterilizing the adults and can cause nymphal mortality. Pyriproxyfen should be applied when a majority of the scales are small nymphs. It is applied at rate of 0.11 lbs-ai per acre. Pyriproxyfen is fairly selective, and although it is not known to disrupt parasitoid activity; it can negatively impact vedalia and other lady beetle populations, as well as lacewing larvae. Do not exceed 0.17 lbs-ai per acre per season. Do not exceed two applications per season. Allow at least 21 days between applications. The restricted entry interval for pyriproxyfen is 12 hours.

•**Buprofezin.** 60 day PHI. Buprofezin (APPLAUD) is an insect growth regulator that disrupts the molting process through chitin synthesis inhibition. The labeled rate for buprofezin in citrus for control of scales is 1.5 to 2.0 lbs-ai per acre. Since this material affects molting, treatment should be made during peak crawler (first instar) emergence. The scales will go through several molts before they are killed, therefore several weeks may pass before populations are noticeably reduced. Do not make more than two applications per season, and allow at least 60 days between applications. Buprofezin is very selective and although it will negatively impact ladybeetle and lacewing larvae to a limited degree, it is very safe to predaceous mites and parasitoids. The restricted entry interval for buprofezin is 12 hours.

CITRUS MEALYBUG

Planococcus citri

DESCRIPTION AND LIFE HISTORY: The citrus mealybug is a sporadic, and extremely damaging and difficult to control pest of citrus, primarily in Yuma County. Citrus mealybugs prefer humid conditions and are most often problem in groves planted on heavier soils or with large and/or closely planted trees where a great deal of tree shading occurs. In citrus, mealybugs spread by crawling from tree to tree, wind, on bird's feet, machinery, and labor crews. Citrus mealybugs are pests of many agricultural and horticultural crops.

Figure 20. Adult female citrus mealybug.

The adult female mealybug is pinkish in color, wingless, and is covered with white-cottony wax, and has a fringe of elongated waxy filaments that extend about the periphery of the body. Fully grown, the female mealybug is about 3 mm long and 1.5 mm in width. The female is mobile, but lacks wings and cannot fly. It will lay 300 to 600 eggs in clumps of 5 to 20 inside egg sacs composed of white cottony-waxy filaments.

The eggs are pink in color and will hatch in 2 to 10 days. The first instar is very active and called a crawler. Crawlers are yellowish-pink in color and are often found congregated upon the egg sac or around the porous glands on citrus fruit.

Figure 21. Citrus mealybug crawlers and nymphs on a lemon fruit.

Citrus mealybugs will pass though two additional instars before molting to an adult female or forming a male pupa. Each instar requires 7 to 16 days to complete. Female nymphs resemble adult female in appearance, while male nymphs are more elongated. Male citrus mealybugs will emerge from their pupae in 7 to 14 days and resemble elongated gnats, with tail filaments. Males are generally about 4.5 mm in length.

Figure 22 Adult male citrus mealybug.

Under optimal conditions, a citrus mealybug will mature from an egg to a reproductively mature adult in about 30 days. Citrus mealybugs overwinter primarily as eggs on the upper roots, trunk, and lower branches of the tree. These eggs will hatch in April and the crawlers will make their way to green twigs and fruit. Subsequent generations develop primarily on the fruit. In Arizona, citrus mealybugs will pass through 4 to 6 overlapping generations.

DAMAGE: Citrus mealybug is a sporadic pest of citrus, occurring primarily in older, well-shaded groves planted on heavy soils. They will feed on the roots, bark, foliage, and fruit. The citrus mealybug injects toxic salvia while extracting plant sap resulting in defoliation, fruit discoloration, fruit splitting, and fruit drop. Additionally, the buildup of honeydew and associated sooty mold fungus can also lead to reduced fruit quality and lowered tree vitality though loss of photosynthetic capacity. Severe infestations can result in 80% defoliation and 100% fruit drop. Damage is most severe in the summer.

Figure 23. Lemons heavily infested with citrus mealybugs.

MONITORING: Citrus mealybug population monitoring should begin in March by examining the trees' trunk and lower branches for overwintering populations. These will appear as areas of white waxy material. Particular attention should be paid to shady groves with large trees where mealybugs have occurred in the previous year and/or there is a large population of nesting birds. As the season progresses, upper branches, twigs, and fruit should be closely monitored for mealybug dispersal. If mealybugs are present during the spring, less disruptive insecticides (spinosad, abamectin) for citrus thrips control should be considered. Inclusion of narrow range oil with thrips insecticide applications will aid in suppressing mealybugs. Once 15 to 20% of the fruit become infested, a curative insecticide treatment should be considered. Insecticide applications should be timed with the emergence of the first instar crawlers for the best efficacy.

Commercially available citrus mealybug pheromones used in conjunction with yellow sticky cards can be utilized to detect mealybug activity. These pheromones will only attract male mealybugs, but can aid in early detection.

When citrus mealybugs are common it is important to determine how much parasitism is occurring. On an infested fruit, gently blow away the accumulated wax revealing the mealybugs. Look for mealybug mummies which contain the parasitoid pupae. Mummies will appear as darkened, swollen, non-winged mealybugs.

A irregular shaped hole will be present on the posterior end of the mummy where a parasitoid adult has emerged. When parasitism is detected, insecticides that are less disruptive to parasitoid activity should be chosen.

Figure 24. Citrus mealybug mummy, with parasitoid exit hole.

CONTROLS:

Cultural:

- **Pruning & hedging.** Hedging trees to prevent touching between trees will help prevent within grove spread of infestations. Additionally, pruning will aid in opening up the canopy to maximize spray penetration and coverage.

- **Equipment Sanitation.** Thorough cleaning of equipment and harvest materials will help prevent the spread of mealybug from an infested grove to others.

Biological:

- **General Predators and Parasitoids.** Ultimately, biological control is the most effective means of controlling citrus mealybug. Parasitoids provide excellent control of the citrus mealybug if they are not disrupted by insecticide treatments. In Arizona, there are several parasitic wasps that prey on mealybug, but an *Anagraphus* sp appears to be most prevalent and important.

Figure 25. *Anagraphus* sp., a common parasitoid of citrus mealybug. Eclosed pupa (right), adult (center), and parasitoid exposed in pupa (left).

Anagraphus sp. parasitoid populations can be augmented with commercially available Anagraphus spp. In addition to parasitoids, native predators include among others, lady beetles, predaceous mites, lacewings, and syrphid flies can aid in mealybug control. Commercial releases of green lacewings appear to aid in mealybug control in some cases.

- **Mealybug Destroyer.** An introduced predator of the citrus mealybug, the larva and adult mealybug destroyer, *Cryptolaemus montrouzieri*, is a voracious feeder of citrus mealybug. Its larvae resemble a mealybug but are about twice as large as the adult citrus mealybug females. The adult is a small beetle with dark brown elytra (hardened front wings) and a light brown head and prothoracic shield (covering over the head). It does not winter well and therefore commercial releases are sometimes necessary where citrus mealybugs were a problem the previous year. Growers should release about 500 *Cryptolaemus* per acre.

Commonly used Chemicals: Chemical control of citrus mealybug can be extremely difficult. Use of selective insecticides for citrus thrips control will often prevent problems with mealybugs by preserving natural enemies. Control is most easily achieved if applications are started during the initial infestation of the fruit, and when the first instar crawlers are prevalent. The addition of narrow range spray oil with the insecticide and high spray volumes (greater than or equal to 200 gal per acre) will increase control. Since citrus mealybug populations can be very clumped in distribution within a grove, it is not usually necessary to treat an entire grove. Hand-gun sprayers can be useful in targeting individually infested trees, and can deliver high volumes at high pressures which will help maximize control. However, no single treatment may offer acceptable control; follow-up applications are

often necessary. New chemical management tactics are currently being researched.

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate that is commonly used for control of citrus mealybug. Chlorpyrifos is applied at an average rate of 4 to 6 lb-ai per acre. Thorough coverage is need for chlorpyrifos to be most effective. It is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects and mites, and parasitoids. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Methidathion.** 14 day PHI. Methidathion (SUPRACIDE) is an organophosphate that is labeled for use in Arizona citrus for control of citrus mealybug. Methidathion is applied at 0.25 to 0.5 lbs-ai per 100 gal. For adequate control, spray volumes of 800 to 1,200 gallons per acre may be required. Thorough coverage is need for methidathion to be most effective. Methidathion may be tank-mixed with spray oils which will aid in efficacy. It is toxic to bees and cannot be applied during bloom. Additionally, methidathion is toxic to predatory insects and mites, and parasitoids, although these effects are short lived. Do not apply more than 5 lbs-ai per acre per application. Do not exceed 2 applications per growing season, and allow at least 45 days between applications. The restricted entry interval for methidathion is: 48 hours when applied at rates less than or equivalent to 2.0 lbs-ai per acre, and 14 days when the rate exceeds 2.0 lbs-ai per acre.

•**Buprofezin.** 60 day PHI. Buprofezin (APPLAUD) is an insect growth regulator that disrupts the molting process through chitin synthesis inhibition. The labeled rate for buprofezin in citrus for control of scales is 1.5 to 2.0 lbs-ai per acre. Since this material affects molting, treatment should be made during peak crawler (first instar) emergence. The mealybugs will go through several molts before they are killed, which may take 21 days before population reduction is noticeable. Do not apply more than two applications per season, and allow at least 60 days between applications. Buprofezin is very selective and although it will negatively impact ladybeetle and lacewing larvae to a limited degree, it is very safe to predaceous mites and parasitoids. The restricted entry interval for buprofezin is 12 hours.

•**Malathion.** 7 day PHI. Malathion is an organophosphate insecticide that has shown efficacy towards citrus mealybug. The labeled rates for malathion in citrus for control of scales is 1.0 to 2.0 lbs-ai per 100 gal. For adequate control, spray volumes of 800 to 1,200 gallons per acre may be required. Thorough coverage is needed for malathion to be most effective. Do not apply when trees are in bloom. Malathion is toxic to insect predators and parasitoids, but is short lived. The restricted entry interval for malathion is 12 hours.

COTTONY-CUSHION SCALE

Icerya purchasi

DESCRIPTION AND LIFE HISTORY: The cottony-cushion scale is an infrequent pest of Arizona citrus. Cottony-cushion scales prefer humid conditions and are most often problem in groves planted on heavier soils or in groves with large and/or closely planted trees where a great deal of tree shading occurs. Cottony-cushion scales spread by crawling from tree to tree, via wind, on bird's feet, on machinery, and with labor crews. Unlike most other scales, the cotton-cushion scale retains its legs and is mobile throughout its life. However, like most scales, only the male is capable of flight.

The adult female scale has a reddish-brown body, black legs and antennae. Tufts of short, black hairs occur in parallel rows along the edge of the body. However, the most distinguishing characteristic of this scale is the large, elongated, grooved cottony-white egg sac. The egg sac (10 to 15 mm in length) becomes 2 to 2.5 times as long as the body of the female. Each egg sac will contain 600 to 1,000 bright-red, oblong eggs.

Figure 26. The adult female cottony-cushion scale is easily recognizable by the white, fluted egg sac.

The eggs will hatch within a few days of being laid under warm conditions, but may require as long as several months under cool conditions. Newly hatched nymphs are bright red with black legs and antennae. Within two weeks they will begin to develop a light-yellow cottony substance on their dorsum, which

becomes denser with age. First and second-instar nymphs settle on leaves and twigs, and are most prevalent in the inner canopy.

On the leaves, the nymphs align themselves along the midrib and veins. Later instars and adults will move to larger twigs and branches, and the trunk. They rarely infest the fruit. The cottony-cushion scale will pass though three nymphal instars before molting to an adult, requiring about 30 days under warm conditions. Generally, there are 3 to 4 generations produced per year in Arizona.

Figure 27. Second instar cottony-cushion scale.

The male cottony-cushion scale is minute, red and winged. It is rarely seen. Third instar male nymphs form pupae within which the male develops its wings.

DAMAGE: Cottony-cushion scale extracts plant sap from leaves, twigs, and branches, reducing tree vigor. If infestations are heavy, leaf and fruit drop can occur along with twig dieback. It also secretes honeydew, which promotes the growth of sooty mold that may discolor fruit and block photosynthesis.

Figure 28. First instar cotton-cushion scale nymphs (left) can be distinguished from first instar vedalia beetles (right) primarily by noting the lack of visible antennae on the vedalia beetle (photo courtesy of Beth-Grafton Cardwell, University of California, Davis).

MONITORING: Monitoring for cottony-cushion scale should begin in early spring by examining the inner canopy twigs and branches. If present during the spring, less disruptive insecticides (spinosad, abamectin) for citrus thrips control should be considered. Inclusion of narrow range oil with thrips insecticide applications will aid in suppressing cottony-cushion scale. Insecticide treatments should only be applied if populations are high and there is no evidence of biological control. Insecticide applications should be timed with the emergence of the 1st instar crawlers for the best efficacy.

In most cases, vedalia beetle, *Rodolia cardinalis*, can be found in groves where cottony-cushion scale is found. Care should be taken to not confuse first instar cottony-cushion scale with early instar vedalia beetle larvae. Although similar in size and color, the scales will have black legs and antennae, whereas the vedalia beetle larvae will have red legs and no visible antennae. Later instar vedalia beetles are gray in color.

CONTROLS:

Cultural:

- **Pruning & hedging.** Hedging trees to prevent touching between trees will help prevent within-grove spread of infestations. Additionally, pruning will aid in opening up the canopy to maximize spray penetration and coverage.

- **Equipment Sanitation.** Thorough cleaning of equipment and harvest materials will help prevent the spread of scales from infested groves to others.

Biological: Natural enemies such as the vedalia beetle and lacewings can effectively control cottony-cushion scale.

Figure 29. Adult vedalia beetle.

- **Vedalia Beetle.** The vedalia beetle, *Rodolia cardinalis*, was introduced from Australia into

California the early 1890s. The adult and larva feed on all stages of the scale. Female beetles lay eggs underneath the scale or attached to the egg sac. Young larvae move into the egg mass and feed on eggs. Later, the larvae feed on all scale stages. The vedalia beetle is susceptible to pyriproxyfen, buprofezin, and broad-spectrum insecticides. When the beetles are present, chemical control is not usually justified since the vedalia beetle will ultimately control most cottony-cushion scale infestations.

Commonly used Chemicals: Although a commonly occurring pest, chemical treatment is rarely needed for cottony-cushion scale in Arizona. Use of selective insecticides for citrus thrips control will often prevent problems by preserving natural enemies. If a heavy population of cottony-cushion scale occurs and few biological control agent are present, insecticides may be necessary, but release of vedalia beetles or lacewing larvae a few weeks following the last application is recommended to reestablish biological control. Adequate chemical control is difficult to achieve but is most effective if applications are started when 1st instars are prevalent. The addition of narrow range spray oil with the insecticide and high spray volumes (greater than or equal to 200 gal per acre) will increase control. Since cottony-cushion scale populations can be clumped in distribution within a grove, it is not usually necessary to treat an entire grove. Hand-gun sprayers can be useful it targeting individually infested trees, and can deliver high volumes at high pressures which will help maximize control. However, follow-up applications are often necessary.

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate that is sometimes used in Arizona for control of mealybugs and whiteflies. However, Lorsban does exhibit limited activity towards control cottony-cushion scale. Chlorpyrifos is applied at an average rate of 4 to 6 lb-ai per acre. Thorough coverage is need for chlorpyrifos to be most effective. It is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects and mites, and parasitoids. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Methidathion.** 14 day PHI. Methidathion (SUPRACIDE) is an organophosphate that is labeled for use in Arizona citrus for control of California red scale. However, methidathion does exhibit good activity towards cottony-cushion scale. Methidathion is applied at 0.25 to 0.5 lbs-ai per 100 gal. For adequate control, spray volumes of 800 to 1,200 gallons per acre may be required. Thorough coverage is need for methidathion to be most effective. It is toxic to bees and cannot be applied during bloom. Additionally, methidathion is toxic to predatory insects and mites, and parasitoids, although these effects are short lived. Methidathion is not labeled for use with oils in Arizona. Do not apply more than 5 lbs-ai per acre per season. Do not exceed 2 applications per growing season, and allow at least 45 days between applications. The restricted entry interval for methidathion is: 48 hours when applied at rates less than or equivalent to 2.0 lbs-ai per acre, and 14 days when the rate exceeds 2.0 lbs-ai per acre.

•**Malathion.** 7 day PHI. Malathion is an organophosphate insecticide that has shown efficacy towards cottony-cushion scale. The labeled rate for malathion in citrus for control of scales is 1.0 to 2.0 lbs-ai per 100 gal. For adequate control, spray volumes of 800 to 1,200 gallons per acre may be required. Thorough coverage is need for malathion to be most effective. Do not apply when trees are in bloom. Malathion is toxic to insect predators and parasitoids, but is short lived. The restricted entry interval for malathion is 12 hours.

•**Pyriproxyfen.** 1 day PHI. Pyriproxyfen (ESTEEM) is an insect growth regulator current being used in Arizona citrus for whitefly and California red scale control. However, pyriproxyfen has demonstrated activity towards cottony-cushion scale. It acts by sterilizing the adults and can cause nymphal mortality. It should be applied when a majority of the scales are small nymphs. It is applied at rate of 0.11 lbs-ai per acre. It is fairly selective, and although it is not known to disrupt parasitoid activity; it can negatively impact vedalia and other lady beetle species, as well as lacewing larvae. Pyriproxyfen drift has been implicated in causing cottony-cushion scale outbreaks where the vedalia beetles were disrupted but the dose was too low to affect the scales. Do not exceed 0.17 lbs-ai per acre per season. Do not exceed two applications per season. Allow at least 21 days between applications. The restricted entry interval for pyriproxyfen is 12 hours.

CITRUS PEELMINER

Marmara gulgosa

DESCRIPTION AND LIFE HISTORY: The citrus peelminer is common pest of citrus throughout Arizona, but is most troublesome in central Arizona where it has occasionally reached extremely damaging levels. Citrus peelminer is very polyphagous (has many hosts) and among others can be found mining oleander,

cotton, melons, peppers and grapes. In citrus, the peelminer can be found mining the stems of flush growth, but are most frequently found mining the fruit peel. Peelminers appear to favor grapefruit and navel oranges, but can be found mining lemons as well. This insect occurs in greatest number in August through October. Populations are thought to buildup in cotton and oleander before moving into citrus.

The adult is a dark-gray moth mottled with brown and cream-colored markings on its wings. The moth is small; about the size of a mosquito (4 mm in length). The moths are active in the morning and early-evening and can live about 11 days. The adult female lays her eggs singly on the fruit surface or on the stems of new flush growth. The number of eggs produced per female may range from 10 to 50 eggs. The eggs are whitish in color, extremely small, oval in shape, convex on top, and with distinct sculpturing. The eggs will hatch in 4 to 5 days.

Figure 30. The citrus peelminer is a dark-gray moth about the size of a mosquito.

The hatching larva immediately begins mining beneath the epidermal cell layer of the peel or stem. There are three distinctive morphological forms for the larvae. The sapfeeding or mining form is flat and laterally sculptured. These larvae are semitransparent-yellowish in color, and can reach a length of about 4.4 mm. The sap feeding form will occur during the first 4 instars and a fifth instar if it occurs. Each instar requires about 3 days to complete. The larvae will then pass through a non-feeding intermediate form, before molting into the spinning form. The spinning form is reddish-brown in color. The spinning form lasts about 1 day and the larvae can reach a length of 4.2 mm.

Figure 31. The spinning form of the citrus peelminer larvae cuts out of the mine and pupates in crevasses on the tree or in the ground litter.

The spinning larva is a non-feeding stage and will exit the mine, lower itself from the fruit by a silken thread to a secluded niche at the leaf axial, or in a crevasse in the bark, or in ground trash. Pupation takes place in a silken cocoon covered with small, white balls. Peelminer cocoons are rarely observed in the field. Pupation requires 10 to 12 days to complete. The entire life cycle generally takes about 30 days to complete.

Figure 32. Citrus peelminers pupate in crevasse on the tree or in ground trash.

Damage: Citrus peelminers have traditionally been more damaging to citrus in central Arizona than in the Yuma area, and heavy infestations appear to be associated with heavy use of broad-spectrum insecticides in nearby cotton (an alternate host for citrus peelminer). Citrus peelminers prefer to infest grapefruit and navel oranges rather than other citrus varieties. Citrus peelminers mine the rind of citrus fruit leaving serpentine patterns which prevents the fruit from being sold for fresh market. Damage is most severe in late

summer and early fall.

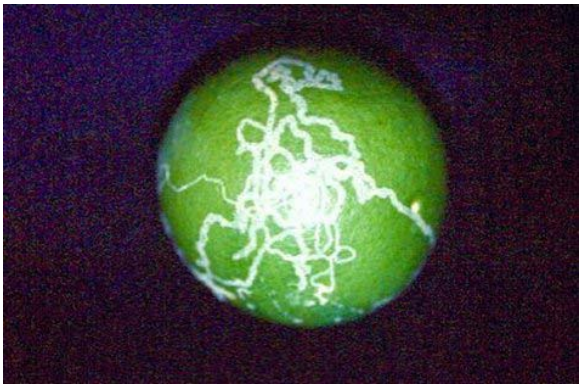

Figure 33. Grapefruit with extensive mining by citrus peelminer.

MONITORING: Currently there is not a reliable way for monitoring citrus peelminer adults so effort should concentrate on sampling larvae. Monitoring for citrus peelminer should begin in July by scouting for the presence of mining in the citrus, and nearby cotton and oleander. Detection of high populations in nearby cotton or oleander may indicate a potential problem in citrus in late summer and fall. From August though November, citrus should be scouted for peelminer more extensively. Check fruit for developing mines. Citrus peelminer tend to prefer fruit on the lower inside canopy, so efforts should be concentrated on the lower 4 ft of canopy.

When mines are found, care should be taken to determine if the larvae are alive since there are a number of predators and parasitoids that prey on peelminers. When 5 to 10% of the fruit have small active mines, with little or no sign or predation, an insecticide application maybe justified.

CONTROLS:

Cultural:

•**Pruning.** Pruning can open the canopy aiding in spray penetration and coverage if curative spraying is required.

•**Multicrop program.** Citrus peelminer cannot survive on Bt cotton. When possible, cotton acreage near citrus should be planted with Bt varieties to reduce local peelminer populations. Avoid using multiple applications of broad-spectrum insecticides for whitefly control in non-Bt cotton near citrus. These applications destroy the parasitoids that normally maintain peelminer populations below damaging levels.

Biological:

•**General Predators and Parasitoids.** Establishing biological control of citrus peelminer is ultimately the best and most effective means of controlling this pest. There are many natural enemies that prey on peelminer larvae, among these are a number of parasitoids. The parasitoid *Cirrospilus coachellae* has proven to be extremely effective. This parasitoid is common, particularly during late summer and early fall. Predators also appear to be important biological control agents of peelminers. The predacious mites, the Yuma spider mite and a *Tydeus* sp., have been observed feeding on citrus peelminer larvae though the peel's upper epidermal layer.

Figure 34. *Cirrospilus coachellae* is an important parasitoid of citrus peelminer (photo courtesy of Beth-Grafton Cardwell, University of California, Davis).

Commonly used Chemicals: Chemical control of citrus peelminer can be difficult. The use of selective insecticides for citrus thrips control and in nearby cotton will often prevent problems with peelminers by preserving natural enemies. The addition of narrow range spray oil with the insecticide and high spray volumes (≥200 gal/ac) will increase inner-canopy coverage and control.

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate that has demonstrated efficacy towards citrus peelminer. Chlorpyrifos is applied at an average rate of 4 to 6 lb-ai per acre. Thorough coverage is need for chlorpyrifos to be most effective. It is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects and mites, and parasitoids and will disrupt biological control. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Spinosad.** 1 day PHI. Spinosad (SUCCESS, ENTRUST), a macrocyclic lactone isolated from the soil microorganism *Saccharopolyspsora spinosa*. It is normally applied to citrus at rates of 0.06 to 0.15 lbs ai per acre. Spinosad is highly effective against citrus peelminer and is the product of choice for peelminer control. However, inner-canopy coverage is essential. Spinosad is relatively nontoxic to beneficial insects and mites. Spinosad may not be applied more than twice per year, and may not be used in nurseries. The restricted entry interval is 4 hours.

CITRUS LEAFMINER
Phyllocnistis citrella

DESCRIPTION AND LIFE HISTORY: The citrus leaf miner appeared in Arizona in the spring of 1999, and currently infests citrus only in the Yuma area. Although citrus leafminer has been a serious pest of citrus in other parts of the world, it has not been especially damaging to Arizona citrus. The citrus leafminer is in the same family as the citrus peelminer, (Gracillaridae), and is similar in general appearance, biology and habit. However, unlike peelminer, the leaf miner is not highly polyphagous and feeds primarily on plants within the citrus family, Rutaceae. In citrus, the leafminer can be found mining the underside of newly formed leaves of flush growth, and are rarely found mining the stems or fruit peel. Leafminers appear to favor grapefruit and navel oranges, but can be found mining lemons in large numbers as well. Mines are found in greatest number in October through December, but can be found on new flush growth throughout the year.

Figure 35. The citrus leafminer moth is about the size of a mosquito with front wings that are silvery in color with darker stripes and black spots on the tips.

The adult has white and silvery iridescent scales on its forewings. The forewings have several black and tan-colored stripes and distinctive black spots on the tips. The hindwings are feathery in appearance. At rest the wings are folded straight over the back. The moth is small; about the size of a mosquito (4 mm in length). The moths are active during early morning and early evening and can live about 11 days. The adult female lays her eggs singly on the underside of small new flush leaves less than 6.5 mm length. Under high leafminer population densities or when flush growth is limited, multiple eggs may be laid per leaf. Eggs are usually laid along the leaf's midvein usually towards the petiole of the leaf.

Figure 36. Citrus leafminer larva (top) is translucent and yellow-green in color, and leaves a serpentine mine (bottom) on the underside of young citrus leaves.

The number of eggs produced per female may ranges from 30 to 75 eggs. Immediately following oviposition, the eggs are translucent and whitish in color, and resemble tiny water droplets. After several days they become yellowish and opaque. They are extremely small measuring 0.2 X 0.3 mm. The eggs will hatch in 2 to 10 days depending on temperature.

The citrus leafminer produces four larval instars, with a total development time of 5 to 20 days. The first three instars are sap-feeding forms, while the fourth instar is a non-feeding spinning form. The hatching larva

immediately begins mining beneath the epidermal cell layer of the leaf leaving nearly invisible mines. These larvae are translucent, light green in color and very difficult to detect. The second and third instars are translucent, yellowish-green and can reach a length of 3 mm. The larger larvae are clearly visible and the mines are easily seen due to increased size and the presence of larval feces within the mine. The mines will meander along the underside of the leaf in a serpentine pattern. The mines resemble a translucent trail of silicone with darkened areas of excrement. The larvae will rarely cross the midvein or to the upper side of the leaf unless overcrowded. The third instar will make its way towards the leaf margin where it will molt into the fourth instar which forms a silken cocoon within the mine. As the silk dries it curls the leaf edge over the cocoon forming a protective pupal cell. The pupa is yellowish-brown and darkens with age. It can easily be revealed by peeling open the pupal cell. The pupation stage requires 6 to 22 days to complete. The entire life cycle requires 14 to 50 days depending on temperature.

Figure 37. Citrus leafminer forms a cocoon within a pupal cell at the leaf margin.

DAMAGE: The citrus leafminer damages citrus by mining the underside of young citrus leaves; the fruit is rarely mined. Leaf mining results in leaf deformation, partial leaf chlorosis, necrosis, and some leaf drop, which ultimately results in a reduction in the tree's photosynthetic capacity. Additionally, the mines provide an entry point for a number of plant pathogens including citrus canker. A single larva can consume 1 to 7 cm^2 of leaf area and leave a 6 to 11.5 inch mine. Leaves with only one mine will often drop from the tree. Leaves with 2 to 3 larvae may receive damage to 50% of the leaf surface, and will often remain on the tree.

Yield reduction in mature trees in uncommon, but has been reported in limes heavily infested with citrus leafminer. Mining of spring flush is more damaging than fall flush since the spring flush is primarily responsible for supporting fruit development. Trees three years of age or less are especially susceptible to leafminer damage. Severe damage to young trees may result in delayed maturity of 1 to 2 years.

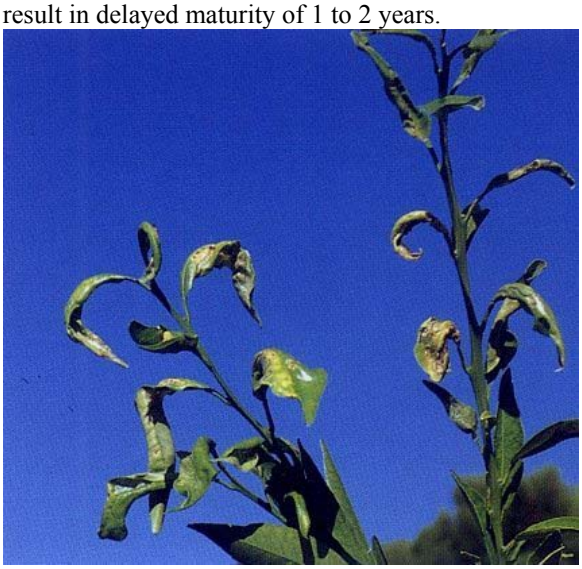

Figure 38. Citrus leafminer mining results in leaf deformation, partial leaf chlorosis, necrosis, and some leaf drop.

MONITORING: Pheromone traps can be used to monitor adult male citrus leafminers, which can aid in determining when high populations occur. However, control decisions should be based on sampling for active larvae, primarily on trees three years of age or less. Monitoring should begin when 50% of the trees are actively flushing, usually February through May and September through October. Randomly check ten leaves from ten pieces of flush and with a hand lens, look for live larvae. The larvae may have to be excised to determine if they are alive. On young trees, treat when 30% of the leaves have active mines with live larvae. Older trees should not be treated with insecticides unless severely infested.

CONTROLS:

Cultural: There are no specific cultural control techniques utilized for citrus thrips.

Biological:

•General Predators and Parasitoids. Naturally occurring biological control of citrus leafminer has been important in keeping this pest from reaching economically damaging levels in Arizona. In one study in December 2002, over 60% of citrus leafminers were killed by predators and parasitoids in Yuma, AZ. It appears that many of the predators and parasitoids that prey on citrus peelminer prey on citrus leafminer as well. In The parasitoid *Cirrospilus coachellae* has

been reported preying on leafminers. This parasitoid is common, particularly during late summer and early fall. Predators also appear to be important biological control agents of leafminers. The predacious mites, the Yuma spider mite and a *Tydeus* sp. have been observed feeding on citrus leafminer larvae though the leave's upper epidermal layer.

Commonly used Chemicals: Although rarely required in Arizona, chemical control of citrus leafminer has proven effective. The addition of narrow range spray oil with the insecticide will significantly increase efficacy.

•**Abamectin.** 7 day PHI. Abamectin (AGRI-MEK) is applied at a rate of 0.006 to 0.024 lbs-ai per acre. It cannot be applied to nurseries or by aircraft. It should always applied in combination with a horticultural spray oil at a rate of not less that 1.0gal per acre. Abamectin is relatively nontoxic to beneficial insects and mites. Do not exceed three applications or 0.048 lbs-ai per acre per year, and allow at least 30 days between applications. The restricted entry interval for abamectin is 12 hours.

•**Imidacloprid.** 0 day PHI. Imidacloprid (PROVADO, ADMIRE) is a neonicotinoid insecticide that mimics the nerve poisoning action of nicotine. Admire is the soil-applied formulation and Provado is the foliar formulation of this chemical. When applied to young trees via the soil through a drip-irrigation, emitter system, or drench, Admire has effectively controlled citrus leafminer. However, at this time, it is not certain if similar efficacy would occur if Admire were injected around trees with a shank applicator followed by flood irrigation. Regardless of application method, it may take as long as six weeks before a fully effective dosage of Admire is distributed within the tree. Admire is applied at a rate 0.25 to 0.5 lbs-ai per acre. No more than 0.5 lbs-ai per acre of Admire may be applied per acre per year. Provado has shown good activity towards leafminers and can be applied at 0.125 to 0.25 lbs-ai per acre. Provado may not be applied during bloom or within 10 days before bloom. Do not exceed 1.0 lbs-ai per acre of Provado per year, and allow at least 10 days between applications. Imidacloprid is safe towards many beneficial insects, especially when applied as a soil treatment. The restricted entry interval for imidacloprid is 12 hours.

•**Spinosad.** 1 day PHI. Spinosad (SUCCESS, ENTRUST), a macrocyclic lactone isolated from the soil microorganism *Saccharopolyspsora spinosa*. Spinosad is normally applied to citrus at rates of 0.06 to 0.15 lbs ai per acre, and is relatively nontoxic to beneficial insects and mites. Spinosad may not be applied more than twice per year, and may not be used in nurseries. The restricted entry interval is 4 hours.

OMNIVOROUS LEAFROLLER
Platynota stultana

DESCRIPTION AND LIFE HISTORY: The omnivorous leafroller feeds on a wide variety of fruit and ornamental trees, and many agricultural and horticultural crops. This small moth was observed infesting citrus in Tulare County, California as early as 1930. By 1950, it had reached pest status throughout Southern California. In 1953, some untreated groves suffered 70 to 80% fruit abortion due to heavy omnivorous leafroller infestations. In Arizona, the omnivorous leafroller is common, but is usually of economic importance on seedling citrus in nurseries.

The adult moth has a 2 to 2.5 cm wing span. The wings are of a fawn or rusty-brown color, and possess a prominent light spot on the coastal margins near the middle of the forewings, as well as other irregularly placed spots. The longevity of the adult is about ten days. Egg laying begins in the spring, usually in February or March. Eggs are deposited on new foliage in clusters or masses with the individual eggs overlapping each other. Usually all the eggs laid by a single female on any one night comprise a single mass. Each female will lay from 100 to 600 eggs within a five-day period. The eggs are then covered by a clear adhesive material. These eggs are flat, elliptical in shape, somewhat transparent or greenish in color, and measure 1 x 65 mm. The eggs will hatch in 5 to 9 days depending on temperature.

Figure 39. The omnivorous leafroller feeds within rolled leaves and is a frequent pest in citrus nurseries.

There are five larval instars. Each larva positions itself

along the midrib of the leaf and encloses itself by rolling the edge of the leaf over with the aid of silken threads. The larva feed within the rolled leaf and when most of the leaf is consumed will move to another leaf. The duration of the larval stage is 13 to 50 days depending on temperature. Pupation takes place within a rolled leaf. The pupal stage requires 4 to 9 days. In field observations in Arizona, it appears that there is a continuous population and this could involve about six generations per year.

DAMAGE: The omnivorous leafroller is a frequent pest of citrus nurseries in Arizona, but rarely reach damaging levels on mature trees. Spring insecticide application targeting thrips probably prevent omnivorous leafroller from becoming troublesome on bearing trees. However, in instances where large leafroller populations have occurred on mature trees, damage can stress trees causing them to drop fruit. Additionally, they will tie leaves to the fruit and feed on the rind, particularly under the button, causing scarring. Damage to young trees can retard growth.

MITE PESTS

MONITORING: Monitoring the omnivorous leafroller should be conducted from spring until fall. Trees should be inspected for rolled leaves which are indicative of omnivorous leaf roller. Although there are no economic thresholds for omnivorous leafroller, populations should not be allowed to become high on nursery trees.

CONTROLS

Cultural: There are no cultural practices that are commonly used to specifically impact omnivorous leafroller.

Biological: There are a number of predators and parasitoids that prey on omnivorous leafrollers, but they usually do not occur in sufficient number provide adequate control.

•**Predators.** Reduviidae, *Nabis* spp., and *Orius* spp. have all been noted preying on omnivorous leafroller in Arizona.

•**Parasitoids.** Parasitoids reported attacking omnivorous leafroller in Arizona include: *Apanteles* spp., *Goniozus platynotae*, *Meteorus dimidiatus*, *Angitia ferrugineliae*, and *Cremastus* sp.

Commonly used Chemicals:

•**Chlorpyrifos.** 28 day PHI at rates exceeding 3 lbs-ai per acre or 14 days PHI for rates of 3 lbs-ai per acre or less. Chlorpyrifos (LORSBAN) is an organophosphate that has demonstrated efficacy towards omnivorous leafroller. Chlorpyrifos is applied at an average rate of 4 to 6 lb-ai per acre. It is toxic to bees and should not be applied during daylight hours during bloom. Additionally, chlorpyrifos is toxic to predatory insects and mites, and parasitoids and will disrupt biological control. Do not apply more than 10 lbs-ai per acre per season. The restricted entry interval for chlorpyrifos is 1 day.

•**Methomyl.** 1 day PHI. Methomyl (LANNATE) is an oxime carbamate that is applied at rates of 0.45 to 0.9 lbs-ai per acre. Methomyl is a restricted use material. It kills beneficial insects, such as mites. Do not apply more than 2.7 lbs-ai per acre per crop. Do not make more than 4 applications per crop. The restricted entry interval for methomyl is 3 days.

TEXAS CITRUS MITE
Eutetranychus banksi

DESCRITPION AND LIFE HISTORY: The Texas citrus mite occurs in North, Central and South America, and Hawaii. In the United States it occurs in all of the major citrus production areas. It has a fairly large host range including among others almonds, figs, *Croton* spp., and citrus. It was first described in 1914 infesting castor and velvet beans in Florida. Since 1955 it has become the most common mite pest of Texas citrus. In Arizona, it was first reported in 1970. It is most common from February until June and then disappears with the onset of high temperatures. However, populations can sometimes be found in November and December. It seems likely this mite may be favored by lower humidity and mild winter temperatures.

Figure 40. Texas citrus mite female (left), and male (right) is a large, cool season mite, predominant during early spring.

Texas citrus mite are relatively large mites and easily seen with the naked eye. Adult females and males vary from tan to a brownish green with dark brown and greenish spots and bars near the lateral margins. The females have a round and flattened body with a dorsal H-shape marking compared to the males whose bodies are smaller and elongated with very long legs. Eggs are deposited along the midrib and near the lateral margins of the leaves on the upper surface. The eggs are flat, disc like with a fine rolled rim or edge. Newly laid eggs are yellowish and become tan and green reddish brown just prior to hatching. Newly hatched larvae are light yellow to tan with pale legs, while older nymphs are similar in color to the adults.

The developmental rate, from egg to adult female, ranges from about 30 days at 59°F to 10 days at 90°F. A single female can produce as many as 37 eggs at an optimal temperature of 82°F. Each female mite will lay 1 to 10 eggs per day with maximum egg production occurring in the mid-80°F. Adult Texas citrus mites can live several months at temperatures in the upper 50°F, but only several weeks when temperatures are in the 80 and 90°F. The sex ratio of the Texas citrus mite is strongly biased for females. Females comprise over 80% of the total adult population at temperatures between 68 and 86°F.

Figure 41. Close up of speckling on a lemon leaf (top) and defoliation of grapefruit in Texas (bottom) caused by Texas citrus mite (bottom photo courtesy of J. Victor French – Texas A&M University, Kingsville).

DAMAGE: The Texas citrus mite primarily feeds on the upper surface of leaves. Feeding can cause stippling and leaf discoloration, and under high populations, can cause some leaf abscission; although this is not common in Arizona. However, under high populations Texas citrus mite will often move to the fruit where feeding may result in rind scarring. Damage is usually most severe on the southern portion of trees where the mite populations tend to be highest.

MONITORING: Citrus should be monitored for Texas citrus mites beginning at petal fall though June. Currently there is no action threshold for Texas citrus mites. It is probably not necessary to treat infestation relegated to the foliage, but in Florida they recommend a miticide if populations reach 15 mites per leaf. In Arizona, we suggest that action may be advisable once the 10% of the fruit has mites.

CONTROLS:

Cultural: There are no specific cultural control techniques utilized for Texas citrus mite.

Biological:
•**Predators.** A number of predators that attack Texas citrus mites including mites, lacewings, predacious thrips, etc.
•**Fungi.** The entomogenous (insect or mite infecting), N*eozygites floridana*, commonly causes disease epizootic (outbreak) in Texas citrus mites in Arizona. This pathogen can quickly reduce large mite populations, and is favored by higher humidity and temperatures.

Commonly used Chemicals: Texas citrus mites are fairly easy to control using miticides (see below for chemical control section for all mites).

YUMA SPIDER MITE
Eotetranychus yumensis

DESCRIPTION AND LIFE HISTORY: The Yuma spider mite was first identified on lemon leaves in 1934 in Yuma, Arizona on the Yuma Mesa, but it occurs elsewhere in Arizona, Southern California and Mexico. There is little detailed information on the life history of this mite. The Yuma spider mite is omnivorous and will feed on plants and other arthropods as well. It is an important predacious mite in Arizona citrus and has been implicated in reducing populations of citrus thrips, woolly whitefly, and citrus leafminer. Among plant species, it has a very large host range including: citrus, almond, apple, arrowweed, grape, ironwood, puncture-vine, rose, and sorghum. Among citrus types, the Yuma spider mite tends to prefer lemons and grapefruit. Yuma spider mites favor warm, dry, dusty conditions. They are most abundant from January though June, but often can be found in July, and October through December.

Figure 42. Yuma spider mites prefer to feed on the underside of leaves. Infestations are conspicuous due to the light webbing that traps dirt and detritus.

Yuma spider mites are medium sized mites measuring about 0.25 mm in length, and are easily seen with the naked eye. They are yellowish to dark pink in appearance with dark pigmentation and red eyespots. The color may vary to some extent depending on their host. Yuma spider mite prefers the underside of leaves where it spins a considerable amount of very light webbing. Infestations of this mite are conspicuous because of dirt and detritus trapped in the webbing. Spherical peach-colored eggs are deposited under the webbing. Infestations are most common in, but not exclusive to, citrus adjacent to dusty roads.

DAMAGE: The Yuma spider mite primarily feeds on the lower surface of leaves. Feeding can cause stippling and leaf discoloration, and under high populations, can cause some leaf abscission, particularly during periods of high winds. The Yuma spider mite has been implicated in a condition known as "fall dieback" which is also associated with high winds, low humidity, and lack of adequate soil moisture. Most frequently this involves new growth resulting in "whiplike" branches devoid of leaves except at the terminal. However, severe foliar damage is not common and economic damage to mature trees is questionable. Because of their predaceous habits, having some Yuma spider mites is beneficial and far outweighs the minor leaf damage inflicted. However, when Yuma spider mites are abundant, they will infest the fruit which is far more serious that foliar infestations. Fruit attacked by Yuma spider mite will suffer rind pitting and scarring.

Figure 43. Pitting on a lemon (top) and leaf speckling (bottom) due to Yuma spider mite feeding. Mites prefer to feed on the underside of leaves.

MONITORING: Citrus should be monitored for Yuma spider mite beginning at petal fall though July. Currently there is no action threshold for Yuma spider mite but some general guidelines exist. It is probably not necessary to treat infestation relegated to the foliage unless populations are extremely high. Florida authorities recommend a miticide if spider mite populations reach 15 mites per leaf. Miticides may be necessary to control Yuma spider mites on the fruit when 10% of the fruit less than 1 inch in diameter is infested or when larger fruit averages 3 to 5 mites per fruit.

CONTROLS:

Cultural:

•**Dust Reduction.** Although reducing the incidence of dust by watering dirt roads adjacent to frequently infested groves may minimize an infestation of Yuma spider mites, this technique is rarely cost effective.

Biological:

•**Predators.** A number of predators that attack Yuma spider mites including predatory mites, lacewings, predacious thrips, etc.

Commonly used Chemicals: Yuma spider mites are fairly easy to control using miticides (see below for chemical control section for all mites).

CITRUS FLAT MITE

Brevipalpus lewisi

DESCRIPTION AND LIFE HISTORY: The flat mite was first observed on lemon at Portersville, California, in 1942. It is common in the desert citrus growing areas of the Southwestern United States, and in the San Joaquin and Sacramento valleys. Among other places, it also occurs in Cuba, Japan, Egypt, Mexico and Australia. The citrus flat mite has a very extensive host range feeding on citrus, alfalfa, peanut, rose, pistachio, pomegranate, cotton, fig, and many others.

Figure 44. Citrus flat mite (seen here hiding in a crevasse of a lemon fruit) is a very small, flat, heat tolerant mite that prefers to feed on the fruit.

The citrus flat mite is fairly heat tolerant and is most abundant from July through September. It can be found in the winter in low numbers hiding in crevasses and buds. The eggs are spherical, extremely small and reddish in color. They are typically deposited on the fruit and leaves. Unlike most other mites infesting Arizona citrus, the citrus flat mite is most often initially found on the fruit, although they can be readily found on the leaves as well. Infestations frequently start at the button end of the fruit and spread from there to places where other insects have fed or oviposited.

The adult is extremely small, barely visible to the naked eye. The adults measure about 0.1 mm in length. It is very flat, and usually amber in color with black pigmentation. Immature flat mites are bright red. Flat mites possess four pairs of legs, two extended forward and two obliquely to the rear.

DAMAGE: Citrus flat mite is often an economically important pest of Arizona citrus primarily in the Yuma area. This mite prefers to feed in locations where some sort of damage has already occurred, and they essentially accentuate that damage. Feeding on the stem end of fruit where thrips have previously fed, results in similar "ringing damage", but that caused by the mites tends to be more irregular. Citrus flat mite damage to fruit less than 1 inch in diameter is very similar to that caused by citrus thrips feeding.

Figure 45. (Top) Lemon on left completely silvered from extensive feeding by citrus flat mite, relative to normal lemon on right; (Bottom) citrus flat mite scarring usually begins where citrus thrips have previously fed, but spreads the scarring in an irregular pattern. Scarring starts out silvery in color, but becomes brown and corky with age, or after fumigation for coloring.

When the mite population is high, the entire fruit surface may become silvered. Feeding damage by this mite on fruit 1 to 2 inches in diameter causes a brownish, corky and scab like appearance, sometimes referred to as russetting, while damage to larger fruit will appear similar, but may not be evident until the fruit has been fumigated for coloring.

The flat mite and related species are known vectors of citrus leprosis virus which can be extremely damaging. This virus causes large chlorotic blothes on the fruit, leaves and stems of citrus. Leprosis virus is currently in Florida, South and Central America, and possibly southern Mexico.

MONITORING: Citrus should be monitored for citrus flat mite spider mite beginning at petal fall though September. Fruit should be inspected closely with a 10X hand lens. Particular attention should be paid to the button area of the fruit. Currently there is no action threshold for citrus flat mite but some general guidelines exist. Miticides may been necessary to control citrus flat mites on the fruit when 10% of the fruit less than 1 inch in diameter is infested, when fruit 1 to 2 inches in diameter average 3 to 5 mites per fruit, or when fruit greater than 2 inches in diameter average 20 mites per fruit.

CONTROLS:

Cultural: There are no common cultural practices designed specifically to impact citrus flat mite.

Biological:
•Predators. A number of predators that attack Citrus flat mites including predatory mites, lacewings, predacious thrips, etc.

Commonly used Chemicals: Citrus flat mites are fairly easy to control using miticides, and are especially sensitive to sulfur (see below for chemical control section for all mites).

TWOSPOTTED SPIDER MITE
Tetranychus urticae

DESCRIPTION AND LIFE HISTORY: The twospotted spider mite is a pest of many agricultural and horticultural crops. It is a cosmopolitan pest, but occurs in Arizona citrus occasionally. The twospotted spider mite is heat tolerant and is most abundant in Arizona citrus in August and September. It appears to be most often problematic in groves suffering from water and heat stress.

Colonies of twospotted mite begin on the underside of mature leaves, but under higher populations they can be found on the tops of leaves, and on the fruit. On the leaves, they prefer to settle along the midvein. On the fruit, this mite prefers to colonize between fruit, where the fruit are clustered together. This mite produces a large amount of fine webbing that may completely cover infested areas of leaves and fruit. The eggs are spherical and translucent when first laid, but become

opaque with age, and can be found scattered about the webbing.

The twospotted spider mite is similar in appearance to the Yuma spider mite. It is greenish to a straw yellow in color, and has "red-eye" spots and dark pigmentation on the sides of its body. The Yuma spider mite usually has more pink pigmentation while the twospotted spider mite has more green pigmentation. However, color variation among these species makes discerning them very difficult. For definitive identification, the Yuma spider mite has two pairs of anal setae (small hairs on the posterior), while the twospotted spider has one pair. In the field, these species can usually be separated based the appearance of their colonies and their eggs (see descriptions).

Figure 46. Twospotted spider mite is an occasionally pest of Arizona citrus that usually occurs during late summer.

DAMAGE: Foliar feeding by the twospotted spider mite results in yellow speckling of the leaves or reddish-brown spots as the damage intensifies. Foliar damage is usually minor and rarely justifies chemical control unless the trees are under environmental stress. On the fruit, more severe damage can occur. Fruit attacked by twospotted spider mite may suffer russetting or brown scabbing to the rind. This damage is sometimes not evident until after the fruit has been fumigated for coloring.

MONITORING: Citrus should be monitored for twospotted spider mite from June through September. Currently there is no action threshold for twospotted mite but some general guidelines exist. It probably is not necessary to treat infestations relegated to the foliage unless populations are extremely high. Florida authorities recommend a miticide application if spider mite populations reach 15 mites per leaf. Miticides may be necessary to control twospotted spider mites on the fruit when 10% of the fruit less than 1 inch in diameter is infested, or when larger fruit averages 3 to 5 mites per fruit.

CONTROLS:

Cultural:
•**Avoid Tree Stress.** Insure that the trees are properly irrigated and fertilizer. Trees irrigated via microsprinklers where volume due to emitter damage tend to experience more twospotted spider mite problems because they are drought stresses and are more prone to shedding leaves.

Biological:
•**Predators.** A number of predators that attack twospotted spider mites including mites, lacewings, predacious thrips, etc.

Commonly used Chemicals: Twospotted spider mites are fairly easy to control using miticides (see below for chemical control section for all mites).

Commonly used Chemicals for control of mites in Arizona citrus:

•**Abamectin.** 7 day PHI. Abamectin (AGRI-MEK) is applied at a rate of 0.006 to 0.024 lbs-ai per acre. It is occasionally used in the Yuma area. It cannot be applied to nurseries or by aircraft. It should always applied in combination with a horticultural spray oil at a rate of not less that 1.0 gal per acre. Abamectin is relatively nontoxic to beneficial insects and mites. Do not exceed three applications or 0.048 lbs-ai per acre per year, and allow at least 30 days between applications. The restricted entry interval for abamectin is 12 hours.

•**Fenpropathrin.** 1 day PHI. Fenpropathrin (DANITOL) is a broad-spectrum pyrethroid insecticide/miticide that is used at a rate of 0.4 lbs-ai per acre. It is recommended that not more than one application be made per year, but there is an allowance of up to 0.8 lbs-ai per acre per year. Fenpropathrin is toxic to beneficial insects and is especially toxic to predatory mites. The restricted entry interval for fenpropathrin is 24 hours.

•**Dicofol.** 7 day PHI. Dicofol (KELTHANE, DICOFOL) is a chlorinated hydrocarbon miticide that is commonly used in Arizona for mite control. It is used at a rate of 3 lbs-ai per acre. Dicofol is relatively safe to beneficial arthropods although predaceous mites maybe suppressed. Do not exceed two applications per year. The restricted entry interval for dicofol is 12 hours.

•**Pyridaben.** 7 day PHI. Pyridaben (NEXTER) belongs to a new class of miticide, the pyridazinones, which act by disrupting cellular respiration through inhibition of mitochondrial electron transfer. Pyridaben is used at 0.25 to 0.50 lbs-ai per acre. It is most active against immature mites as a contact poison, and is relative safe to beneficial arthropods although predacious mites may be suppressed. The restricted entry interval is 12 hours.

•**Wettable Sulfur**. 0 day PHI. Wettable sulfur (MICROTHIOL, BEN SUL, SPRAY SULFUR, KUMULUS, and others), is applied to thoroughly cover foliage as soon as mites are detected. Rates vary slightly among products and range from 8 to 100 lbs of product per acre. Addition of sulfur with insecticides targeting citrus thrips will often preventively control mites. To avoid foliar scorching: do not apply in combination with any oils or within 21 days of previous oil application, or when temperatures are high; young trees are particularly susceptible. The restricted entry interval varies among products from 12 to 24 hours.

Commonly used Chemicals: In Arizona, twospotted spider mites are fairly easy to control using miticides.

•**Abamectin.** 7 day PHI. Abamectin (AGRI-MEK) is applied at a rate of 0.006 to 0.024 lbs-ai per acre. Abamectin is occasionally used in the Yuma area. It cannot be applied to nurseries or by aircraft. It should always applied in combination with a horticultural spray oil at a rate of not less that 1.0 gal per acre. Abamectin is relatively nontoxic to beneficial insects and mites. Do not exceed three applications or 0.048 lbs-ai per acre per year, and allow at least 30 days between applications. The restricted entry interval for abamectin is 12 hours.

•**Fenpropathrin.** 1 day PHI. Fenpropathrin (DANITOL) is a broad-spectrum pyrethroid insecticide/miticide that is used at a rate of 0.4 lbs-ai per acre. It is recommended that not more than one application be made per year, but there is an allowance of up to 0.8 lbs-ai per acre per year. Fenpropathrin is toxic to beneficial insects and is especially toxic to predatory mites. The restricted entry interval for fenpropathrin is 24 hours.

•**Dicolfol.** 7 day PHI. Dicofol (KELTHANE, DICOFOL) is a chlorinated hydrocarbon miticide that is commonly used in Arizona for mite control. It is used at a rate of 3 lbs-ai per acre. Dicofol is relatively safe to beneficial arthropods although predaceous mites maybe suppressed. Do not exceed two applications per year. The restricted entry interval for dicofol is 12 hours.

•**Pyridaben.** 7 day PHI. Pyridaben (NEXTER) belongs to a new class of miticides, the pyridazinones, which act by disrupting cellular respiration through inhibition of mitochondrial electron transfer. Pyridaben is used at 0.25 to 0.50 lbs-ai per acre. It is most active against immature mites as a contact poison, and is relative safe to beneficial arthropods although predacious mite may be suppressed. The restricted entry interval is 12 hours.

•**Wettable Sulfur**. 0 day PHI. Wettable sulfur (MICROTHIOL, BEN SUL, SPRAY SULFUR, KUMULUS, and others), is applied to thoroughly cover foliage as soon as mites are detected. Rates vary slightly among products and range from 8 to 100 lbs of product per acre. Addition of sulfur with insecticides targeting citrus thrips will often preventively control mites. To avoid foliar scorching: do not apply in combination with any oils or within 21 days of previous oil application, or when temperatures are high; young trees are particularly susceptible. The restricted entry interval varies among products from 12 to 24 hours.

OTHER PESTS OCCURRING IN ARIZONA

Rarely of economic importance

Citrus red mite, *Panonychus citri*

Citrus rust mite, *Phllocoptuta olveivora*

Lewis spider mite, *Eotetranychus lewisi*

Citricola scale, *Coccus pseudmagnoliarum*

Barnacle scale, *Ceroplates cirripediformis*

Brown soft scale, *Coccus hesperidum*

Long-tailed mealybug, *Pseudococcus longipinus*

Navel orangeworm, *Amyelois transitella*

Orange dog, *Papilio cresphontes*

Citrus looper, *Anacamptodes fragilaria*

Raisin moth, *Ephestia figulilella*

Leafhoppers, *Empoasca fabae, Empoasca mexara*

Spirea aphid, *Aphis citricola*

Green peach aphid, *Myzus persicae*

Cowpea aphid, *Aphis craccivora*

Foxglove aphid, *Aulacorthum solani*

Melon aphid / cotton aphid, *Aphis gossypii*

Fuller rose beetle, *Pantomorus cervinus*

Katydids, *Scudderia furcata*, *Microcentum retinerve*

Grasshoppers, various – *Melanoplus* spp., *Schistocerca* spp.

False chinchbug, *Nysius raphanus*

White grubs, *Polyphylla* spp., *Cyclocephala* spp.

Southern fire ant, *Solenopsis geminate*

Western subterranean termite, *Reticulitermes hesperus*

Snails, *Runina decollate, Succinea californica*

Slugs, *Derocerus* sp, *limax* sp., *Milax* sp.